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Forest Health Protection Report

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Intermountain Region, State and Private Forestry

A Follow-up Biological Evaluation of the Douglas-fir Tussock Moth Outbreak in Southern Idaho

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ABSTRACT

The most expansive Douglas-fir tussock moth outbreak recorded in southern Idaho was detected in 1990 during the annual aerial detection survey. By 1992, more than 400,000 acres had been defoliated. Eighty-eight percent of the Douglas-fir trees and 95 percent of the grand fir trees which were more than 89 percent defoliated died between 1991 and 1995. This outbreak coincided with a significant drought period which probably contributed to the high levels of mortality. Douglas-fir beetle activity within the outbreak boundary increased following defoliation.

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378. Weatherby, J. C.; Barbouletos, T.; Gardner, B. R.; Mocettini, P. A follow-up biological evaluation of the Douglas-fir tussock moth outbreak in southern Idaho. [Boise, Idaho: U.S. Dept. of Agriculture, Forest Service, Intermountain Region, State & Private Forestry, Forest Health Protection; 1997]: 14 p. (Report (United States. Forest Service. Intermountain Region. Forest Health Protection); 97-01).

INTRODUCTION

The Douglas-fir tussock moth, *Orgyia pseudotsugata* McDunnough (DFTM), is a serious defoliator of Douglas-fir, *Pseudotsuga menziesii* and true firs, *Abies spp.*, in western North America. The general biology and outbreak chronology of DFTM populations are well documented in the literature (Brookes et al., 1978).

The most expansive DFTM outbreak recorded in southern Idaho was first detected in 1990 during the annual aerial detection survey. Conifers on approximately 50,700 acres were defoliated (Knapp et al., 1991). The outbreak continued to expand in 1991 encompassing more than 312,000 acres of defoliation (Knapp et al., 1992). Much of the same area was defoliated again in 1992 along with adjacent fringe areas. The total area of defoliation was estimated at 418,000 acres (Knapp et al., 1993).

This report updates the results of survey work begun in 1991. The 1991 sampling protocol and predictions concerning impacts and population trends are described in Report No. R4-92-01 entitled "A Biological Evaluation of the Douglas-fir Tussock Moth Outbreak in Southern Idaho, 1991." Information gathered since 1991 has been updated and is summarized in this report.

METHODS

Early Warning System -- The early warning system is designed to detect population increases one to two years prior to an outbreak and has been used continuously in southern Idaho since 1982. This system involves deployment of five pheromone-baited traps at each site, following the procedures outlined by Daterman et al. (1979), to detect and monitor male moths. "An average trap catch of 25 moths or more can indicate that the local population is approaching the outbreak stage" (Daterman et al., 1979).

In southern Idaho, trap catch data from 1982 to 1991 exist for 21 permanent sampling sites (Weatherby et al., 1991); therefore these sites, except for two sites on the Salmon National Forest, one site on the Boise National Forest, one site on the Payette National Forest, and one site on State lands, were again used as sampling sites from 1992 to 1995. Seventy-eight additional sites were added on the Boise and the Payette National Forests in order to monitor expansion of the current outbreak and to improve the predictive capabilities of the early warning system during future outbreaks. The number of male moths captured within each trap was recorded and the mean moth catch per trap was calculated for each site.

Aerial Detection Surveys – Aerial detection surveys were conducted annually from 1990 to 1995. Areas of defoliation were sketch mapped by defoliation intensity. This information was digitized and plotted on 1/2 inch to the mile forest maps. Defoliation intensities were assigned based upon the proportion of the entire crown displaying visible feeding damage. Lightly defoliated areas were designated when visible feeding damage occurred on less than 25 percent of the entire crown. Moderately defoliated areas were designated when visible defoliation occurred on more than 24 percent but less than 75 percent of the entire crown. Heavily defoliated areas were designated when visible damage occurred on more than 74 percent of the entire crown. Defoliated areas and defoliation intensities usually intermingled with non-defoliated areas. It is virtually impossible to accurately plot all individual patches of like defoliation intensity. Instead, nearby pockets of defoliation in the same defoliation intensity class were combined into larger polygons. While no new pockets of defoliation were detected in 1993, pockets of mortality attributed to DFTM were mapped along with any detectable bark beetle activity. Similar surveys were performed in 1994 and 1995.

Ground Surveys -- In the summer of 1991, Forest personnel on the Boise, Payette, and Sawtooth National Forests were asked to identify areas they would like to have ground surveyed to obtain information concerning DFTM populations, individual tree defoliation rates, etc., with which to predict population trends and fate of affected trees. Many of the identified areas were located within the outbreak boundaries as drawn from aerial detection surveys.

The following sampling scheme was utilized. In areas with obvious defoliation, a five-plot transect was permanently installed. The first plot was located two chains from the road, and the remaining four plots were spaced three chains apart along a line that contoured the slope. Data were collected from a 40-basal area factor (BAF) variable plot. The center of the plot was located and each tree within the variable plot was numbered. At each plot, site and individual tree data were collected. Site data included elevation, slope, aspect, habitat type and physiographic site. Tree data included species, diameter at breast height (DBH), 5- and 10-year radial growth, cover class and the occurrence of other pests. In addition, defoliation ratings in percent of total needle complement missing as a result of defoliating insect activity was visually estimated and recorded.

The plots were visited annually for 5 years and the condition of each tree was noted. Trees were classified as alive or dead. Trees with numerous bark beetle attacks were considered mass attacked and bark beetles were the causal agent of mortality. Strip attacks and pitch outs were noted but the trees were recorded as living. Trees that were defoliated and died without any other apparent causes of mortality were classified as dead and the cause of mortality was attributed to tussock moth defoliation.

RESULTS AND DISCUSSION

Early Warning System - The early warning system has been used continuously in southern Idaho since 1981. The purpose of this system is to detect population trends using pheromone-baited traps that are easy to deploy and which selectively monitor tussock moth populations. The historical sites selected in 1981 were in areas with a history of defoliation caused by DFTM. Fifteen years of annual trap catch data for these historical sites are summarized in Table 1. Trap catches are highly variable within and between sites and the significance of the catches is sometimes difficult to interpret. Figure 1 displays the mean trap catch for all of the historical sites since 1981 and the acres of defoliation detected during annual aerial detection surveys. Two population peaks were detected: one in 1983 and one in 1990. These peak catches corresponded with the first year of detectable defoliation associated with the two most recent outbreaks. From this data set it is difficult to determine whether the early warning system provided advance warning of impending outbreaks; however during both outbreaks, it did appear to reflect general population trends.

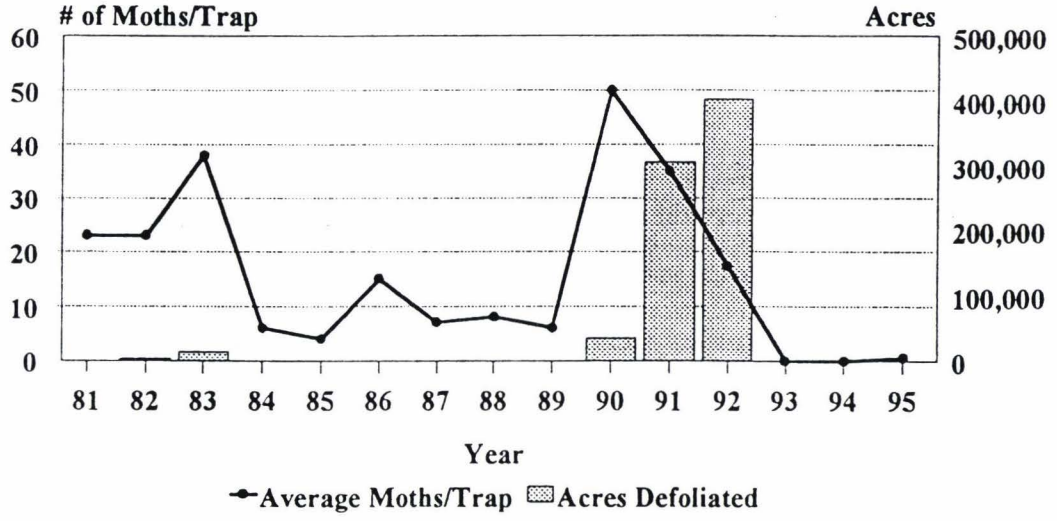

Figure 1. Mean number of Douglas-fir tussock moths captured per pheromone-baited trap for all of the historical sites since 1981 and acres of defoliation attributed to Douglas-fir tussock moth detected during annual aerial detection surveys.

Table 1. Mean catches of male Douglas-fir tussock moths in pheromone-baited sticky traps for permanent trapping sites in southern Idaho, 1981-1995.

Site	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Boise NF															
Bear Ck.	*	0.0	32.8	0.4	0.0	1.2	1.4	0.6	0.2	31.6	25.6	1.4	0.0	0.0	0.0
Skunk Ck.	0.2	0.6	29.0	0.0	1.0	1.2	0.2	0.2	0.0	5.3	*	1.0	0.0	0.0	0.0
Deer Point	*	*	*	*	*	*	*	*	*	65.6	35.6	2.0	0.0	0.0	0.0
Payette NF															
Adams Ck.	*	53.6	39.6	7.8	4.0	17.6	8.8	1.8	2.6	78.6	40.4	1.0	0.0	0.0	0.0
Barinaga	*	*	44.2	0.4	2.8	4.0	2.0	0.0	1.0	9.6	8.0	0.4	*	0.0	0.0
Bear Saddle	*	15.2	44.0	1.0	0.2	0.2	0.4	0.0	0.0	84.8	8.4	0.2	0.0	0.2	0.8
E. Fk. Brownlee	*	61.2	50.6	2.6	3.4	27.0	6.0	0.2	0.4	56.8	6.0	5.4	0.0	0.0	0.0
Fourbit Ck.	*	49.8	42.8	*	4.8	30.4	2.0	2.2	1.2	37.0	*	*	*	*	*
McDowell Trail	*	*	35.8	5.0	6.8	24.6	1.2	0.0	0.0	26.8	3.4	*	0.0	0.0	0.0
Olive Ck.	*	36.8	51.2	14.6	10.5	46.8	9.8	3.2	0.5	19.4	7.0	10.4	0.0	0.0	0.0
Seid Ck.	*	*	17.4	11.2	*	27.2	4.8	1.6	0.4	51.6	18.4	5.0	0.0	0.2	0.0
Stacy Ck.	*	*	42.8	18.0	8.8	3.8	5.0	0.0	0.4	63.2	43.2	2.0	0.0	0.2	0.0
Salmon NF															
Colson Ck.	*	15.2	39.0	3.2	*	7.2	5.2	14.0	0.6	0.4	*	*	*	*	*
Lick Ck.	*	7.6	38.4	0.6	*	6.0	0.6	28.5	0.6	0.4	*	*	*	*	*
Sawtooth NF															
Little Water Gulch	3.8	13.6	27.0	17.2	0.0	34.6	26.6	4.0	32.5	102.0	76.0	31.4	0.0	0.2	0.0
Virginia Gulch	0.6	2.0	26.8	1.8	0.0	4.8	6.8	2.6	0.4	58.6	62.0	25.2	0.0	0.0	0.0
Idaho State Lands															
Sharps Canyon	19.4	16.2	41.2	1.3	5.2	22.6	8.4	36.4	9.2	53.2	*	18.8	0.0	0.0	0.0
BLM Lands															
Dewey Peak	64.0	*	*	15.0	1.6	33.7	38.6	47.0	36.3	80.4	73.0	121.8	0.0	7.2	49.2
Mill Ck.	47.6	*	*	6.6	0.0	0.4	0.0	0.2	0.2	53.0	87.6	38.8	0.0	0.6	1.6
New York Summit	*	*	*	0.0	*	1.8	3.8	15.0	12.6	71.8	82.8	11.8	0.0	0.0	1.4
S. Fk. Boulder Ck.	*	*	*	0.7	0.2	1.8	0.2	0.8	2.2	96.8	61.0	31.8	*	0.0	0.0
Mean	22.6	22.7	37.7	5.7	3.1	14.9	6.6	7.8	5.1	50.1	39.9	18.1	0.0	0.5	2.9

* = Not sampled.

Seventy-eight additional sites were monitored with pheromone traps from 1991 through 1995 (Table 2). Higher 1991 trap catches were found in areas which sustained defoliation or which were located within a 1/2 mile radius of defoliated areas as compared to catches at sites that were not defoliated. At defoliated sites, the mean trap catch was 51.3 moths while in non defoliated areas the mean trap catch was 13.8 moths. At most sites, trap catches dropped off precipitously in 1992 as did the actual DFTM population levels. By 1993, only 1 moth was captured and that was at a site that had not been defoliated between 1990 and 1992. Trap catches remained at very low levels at all sites in 1994 and 1995 except for the Dewey Peak site in the Owyhee Mountains. In 1995, the mean trap catch at the Dewey Peak site was 49.2 moths per trap. Considering the 1995 trap catches, we would not expect to detect DFTM caused defoliation in 1996 at any site except for perhaps the Dewey Peak site. The mean trap catch at the Dewey Peak site exceeded the 25 moths per trap threshold reported by Daterman et al. (1979) and in this area DFTM populations could be nearing outbreak status.

Aerial Detection Surveys -- Areas of defoliation detected during annual aerial detection flights expanded from 50,700 acres in 1990 to 418,00 acres in 1992. The defoliation occurred in 5 discrete outbreak centers. The Boise River infestation was first detected in 1990 in the vicinity of Trinity Lakes and Steel Mountain. By 1992 it encompassed approximately 354,500 acres, making it the largest of the 5 infestations. A sequence of maps illustrating the progression of this outbreak is displayed in Figure 2. By 1993, no new defoliation was detected and normal spring growth on living trees resumed. During the 1993 aerial survey, previously defoliated areas with normal spring growth were discriminated from areas where most of the trees died and only the mortality centers attributed to defoliation were mapped. Within defoliated areas, bark beetle activity was difficult if not impossible to map because defoliated trees had little foliage and the fading crowns associated with bark beetle attacks were not visible.

In 1994, bark beetle activity in previously defoliated areas was detected and by 1995 a major Douglas-fir beetle, *Dendroctonus pseudotsugae* outbreak was apparent in the vicinity of previously defoliated stands (Figure 3). Approximately 70 percent of the Douglas-fir beetle activity detected on the Boise and Sawtooth National Forests in 1995 was concentrated in and around the areas of defoliation. Prior to the outbreak, only 30 percent of the Douglas-fir beetle activity on the Boise and Sawtooth National Forests was concentrated in the area where the outbreak was to occur (Figure 4). While there are many other factors that probably contributed to the coalescence of Douglas-fir beetle activity in this area, it appears to be related to defoliation.

Ground Surveys -- Impact plots that were established in 1991 were revisited annually through 1995. Unfortunately, many of the impact plots were salvage logged; particularly in the Sagehen/Squaw Creek infestation. These plots were deleted from the analysis of early outbreak (1991) and post-outbreak (1995) stocking levels. Impact transects were classified by defoliation intensity into area damage classes according to the procedures explained by Weatherby et al. (1992). Only transects in the moderate, heavy and very heavy damage classes were revisited because we anticipated mortality in these areas as opposed to areas in the lightly damaged class where defoliation levels were not expected to cause mortality.

All the transects in the very heavy damage class are located in the Boise River infestation. These plots are found on Douglas-fir or subalpine fir, *Abies lasiocarpa* habitat types that are dominated by Douglas-fir trees. In the heavy damage class all the transects are located in Douglas-fir or subalpine fir habitat types located in the Boise River infestation except for two transects in the Mann Creek/Brownlee Creek infestation found on fairly dry grand fir, *Abies grandis* habitat types. In the moderate damage class, one transect is located in the Mann Creek/Brownlee Creek infestation and three transects are located in the Boise River infestation. Samples from grand fir habitat types that are typical of the Sagehen/Squaw Creek infestation are severely unrepresentative due to salvage logging operations.

Table 3 summarizes the transect and mean stocking levels for all trees greater than 5 inches DBH that existed at the beginning of the outbreak compared to stocking levels found in 1995 (post-outbreak) for each damage class. In the very heavy damage class, stocking levels averaged 63.8 trees per acre in the early phases of the outbreak. Ninety percent of these trees were Douglas-fir trees. Five years after the initiation of the outbreak, stocking levels had been drastically reduced and a mean of 15.7 trees per acre remained alive. This represents a 25 percent

Table 2. Mean catches of male Douglas-fir tussock moths in pheromone-baited sticky traps for additional trapping sites added in 1991.

Site	Town.	Range	Section	1991	1992	1993	1994	1995
Boise NF								
Bogus X-Ski	5N	3E	16	24.0	0.0	0.0	0.0	0.0
Shafer Butte	5N	3E	10	14.6	0.8	0.0	0.0	0.2
Squaw Ck.	13N	2E	9	18.2	1.2	0.0	0.2	0.0
Tamarack Flat	12N	2E	8	45.0	0.0	0.0	0.0	0.0
Antelope Trail	12N	2E	10	30.6	0.0	0.0	0.0	0.0
Little Sagehen	11N	2E	1	31.6	0.0	0.0	0.0	0.0
Cottonwood Ck.	12N	2E	33	47.3	3.8	0.0	0.2	0.0
M. Fk. Payette R.	11N	5E	4	4.8	1.4	0.0	0.0	0.0
Silver Ck. CG.	12N	6E	19	3.2	0.0	0.0	0.0	0.0
Hardscrabble	11N	5E	31	1.8	0.0	0.2	0.0	0.0
W. Fk. Sixmile Ck.	11N	4E	22	3.2	0.0	0.0	0.0	0.0
Lower Scriver Ck.	10N	4E	20	11.8	5.0	0.0	0.0	0.0
Lost Man Ck.	5N	9E	31	117.4	44.6	0.0	0.0	0.0
Roaring R.	5N	8E	26	95.2	52.0	0.0	0.0	0.0
Trinity Lk. Rd.	4N	9E	29	*	41.4	0.0	*	0.0
Cow Ck.	3N	10E	4	53.6	87.4	0.0	0.2	0.0
Red Warrior Ck.	4N	10E	20	92.0	55.8	0.0	0.2	0.0
W. Parks Ck.	3N	9E	2	80.6	9.0	0.0	0.0	0.0
Fairview Ck.	3N	10E	17	49.4	9.0	0.0	0.4	0.0
Upper Rock Ck.	8N	6E	36	6.6	0.2	0.0	0.0	0.0
Beaver Ck. Summit	8N	7E	15	23.4	0.2	0.0	0.0	0.0
Banner Ridge	8N	7E	14	39.2	0.0	0.0	0.0	0.0
Banner Ck.	8N	8E	29	8.0	0.6	0.0	0.0	0.0
Crooked R.	8N	8E	34	25.8	0.2	0.0	0.0	0.0
Willow Ck.	7N	8E	14	52.4	1.0	0.0	0.0	0.0
Rough Ck.	11N	9E	31	*	0.0	0.0	0.0	0.0
Horse Ck.	10N	8E	16	12.2	1.4	0.0	0.0	0.0
O'Keefe Ck.	10N	7E	25	18.0	4.2	0.0	0.0	0.0
Park Ck. CG.	9N	7E	13	1.4	2.4	0.0	0.0	0.0
Whitehawk	11N	8E	20	*	0.2	0.0	0.0	0.0
Wilson Ck.	12N	7E	34	*	0.6	0.0	0.0	0.0
Threemile	11N	7E	19	*	0.6	0.0	0.0	0.0
Scott Ck.	10N	6E	15	*	0.6	0.0	0.0	0.0
Slaughterhouse	9N	7E	20	61.6	9.2	0.0	0.2	0.0
Warm Lake Ck.	15N	7E	9	0.0	0.0	0.0	0.0	0.0
Tule Lk.	15N	6E	12	*	0.6	0.0	0.0	0.2
Rice Ck.	14N	7E	18	0.6	0.0	0.0	0.0	0.0
Lodgepole Ck.	14N	7E	5	1.4	0.4	0.0	0.0	0.0
Bear Ck.	4N	10E	7	25.6	1.4	0.0	0.0	0.0
Skunk Ck.	12N	4E	11	*	1.0	0.0	0.0	0.0
Deer Point	5N	3E	29	35.6	2.0	0.0	0.0	0.0
Payette NF								
Hitt Ck.	14N	5W	27	8.4	13.0	0.0	0.0	0.0
Mann Ck.	14N	5W	4	16.6	0.8	0.0	0.0	0.0
South Pine	15N	5W	25	25.2	0.2	0.0	0.0	0.0
Mill Ck. Rd.	15N	4W	6	51.8	0.6	0.0	0.0	0.0
Tool Cache	15N	5W	15	17.6	0.4	0.0	0.0	0.0
Middle Brownlee	15N	5W	3	7.8	0.2	0.0	0.0	0.0
Cottonwood	15N	5W	8	12.8	0.2	0.0	0.0	0.4
Rapid Ck.	17N	4E	26	10.8	0.4	0.0	0.0	0.0
Powelson Ck.	17N	5E	20	*	0.0	0.0	0.0	0.0

Table 2. (Cont.) Mean catches of male Douglas-fir tussock moths in pheromone-baited sticky traps for additional trapping sites added in 1991.

Site	Town.	Range	Sect.	1991	1992	1993	1994	1995
Payette NF (Cont.)								
Sloan Point	16N	4E	1	20.0	0.0	0.0	0.0	0.0
Browns Ck.	20N	2E	18	9.6	0.0	0.0	0.0	0.0
Sixmile Ck.	20N	2E	28	16.6	1.6	0.0	0.0	0.0
Last Chance	19N	2E	15	3.6	1.6	0.0	0.0	0.0
Brundage Ski	19N	2E	12	3.4	0.2	0.0	0.2	0.0
Bear Basin	19N	3E	30	0.3	0.0	0.0	0.0	0.0
Yantis Ditch	5S	1W	10	9.2	1.4	0.0	0.0	0.0
Chokecherry	4S	1W	12	*	0.0	0.0	0.0	0.0
Ant Basin Ck.	5S	1W	34	1.8	0.0	0.0	0.0	0.0
Mud Ck.	5S	1W	13	4.0	0.8	0.0	0.0	0.0
Round Valley Ck.	20N	1E	6	*	0.0	0.0	0.0	0.0
E. Fk. Lost Ck.	6S	1W	21	6.0	1.2	0.0	0.0	0.2
Sheep Ck.	7S	1W	17	0.0	1.2	0.0	0.0	0.0
Lost Ck.	8S	1W	14	5.4	4.4	0.0	0.0	0.0
4th of July Ck.	7S	2W	1	7.2	2.4	0.0	0.0	0.0
Bluebunch	17N	1E	1	5.2	0.2	0.0	0.0	0.0
Squaw Flat	17N	2E	32	3.4	0.6	0.0	0.0	0.0
E. Fk. Weiser R.	17N	1E	21	17.0	3.0	0.0	0.2	0.0
Dry Beaver Ck.	17N	1E	10	18.6	0.4	0.0	0.0	0.0
Joker/Dewey	17N	2E	13	0.4	0.0	0.0	0.0	0.2
Cabin Ck. CG.	15N	1E	12	4.2	2.2	0.0	0.2	0.0
Johnson Park	9S	2W	32	3.4	0.4	0.0	0.0	0.0
Goodrich Ck.	16N	2W	7	0.6	0.0	0.0	0.0	0.2
Orchid Canyon	16N	2W	4	7.4	10.8	0.0	0.0	0.4
Adams Ck.	14N	6W	23	40.4	1.0	0.0	0.0	0.0
Barinaga Corral	5S	2W	23	8.0	0.4	*	0.0	0.0
Bear Saddle	15N	5W	31	8.4	1.4	0.0	0.2	0.8
E. Fk. Brownlee	16N	4W	3	6.0	5.4	0.0	0.0	0.0
McDowell Trail	17N	2W	18	3.4	*	0.0	0.0	0.0
Olive Ck.	17N	2W	6	7.0	10.4	0.0	0.0	0.0
Seid Ck.	16N	4W	21	18.4	5.0	0.0	0.2	0.0
Stacey Ck.	14N	6W	24	43.2	2.0	0.0	0.2	0.0
Sawtooth NF								
Paradise Springs	3N	10E	33	71.0	22.0	0.0	1.0	0.2
Grouse Ck.	3N	10E	36	67.6	28.0	0.0	0.2	0.0
M. Fk. Grouse Ck.	2N	11E	31	75.8	0.0	0.0	0.0	0.0
Little Water Gulch	3N	12E	7	76.0	31.4	0.0	0.2	0.0
Virginia Gulch	3N	11E	9	62.0	25.2	0.0	0.0	0.0
Idaho State Lands								
Pine Ridge Rd.	7S	1W	35	25.0	5.0	0.0	0.0	0.0
Sharps Canyon	2N	19E	36	*	18.8	0.0	0.0	0.0
BLM Lands								
Dewey Peak	6S	4W	3	73.0	121.8	0.0	7.2	49.2
Mill Ck.	8S	5W	12	87.6	38.8	0.0	0.6	1.6
NY Summit	4S	3W	32	82.8	11.8	0.0	0.0	1.4
S. Fk. Boulder Ck.	8S	5W	24	61.0	31.8	*	0.0	0.0

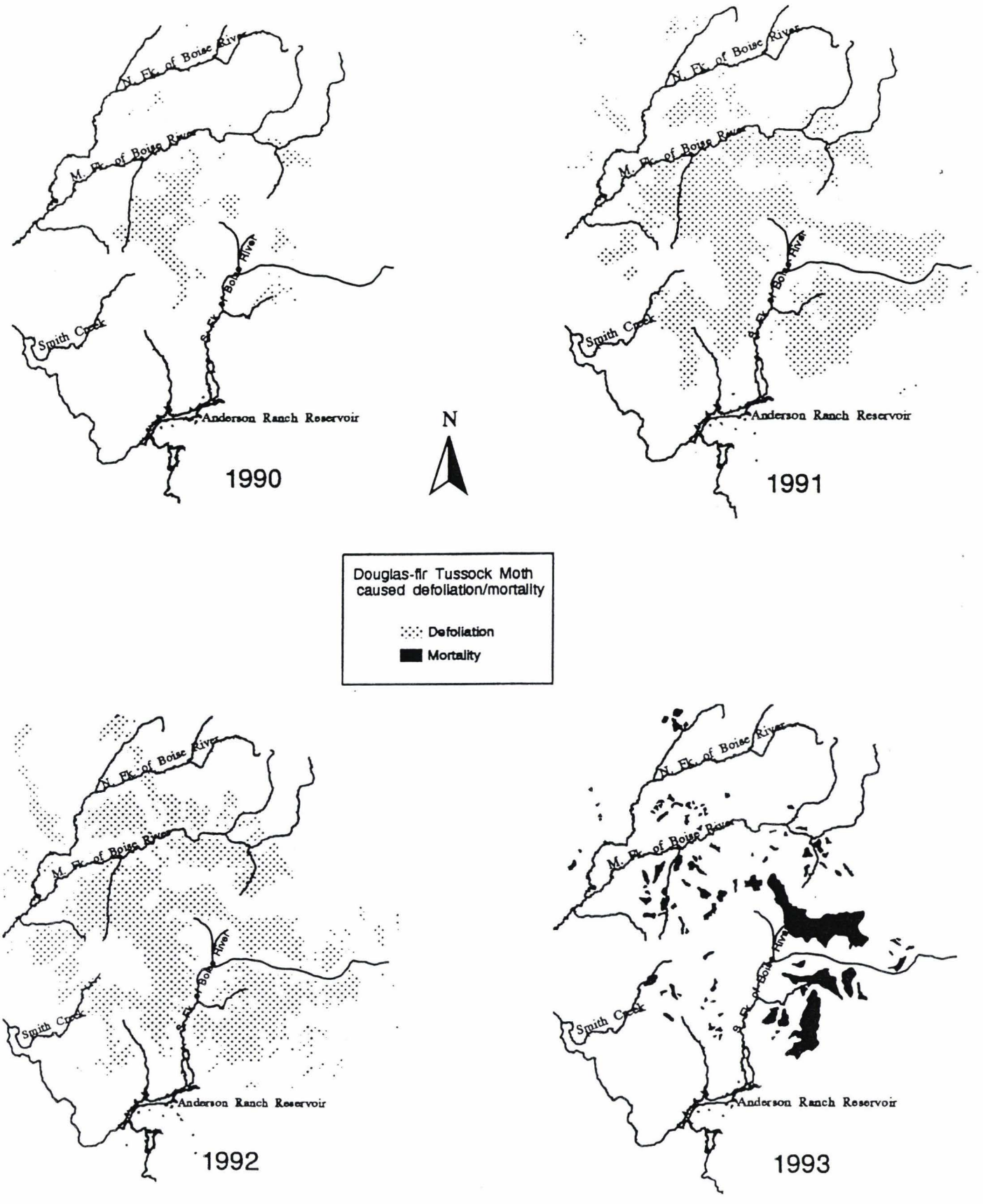

Figure 2. Areas of defoliation and resultant mortality caused by Douglas-fir tussock moth detected during annual aerial surveys of the Boise River infestation (1990-1993).

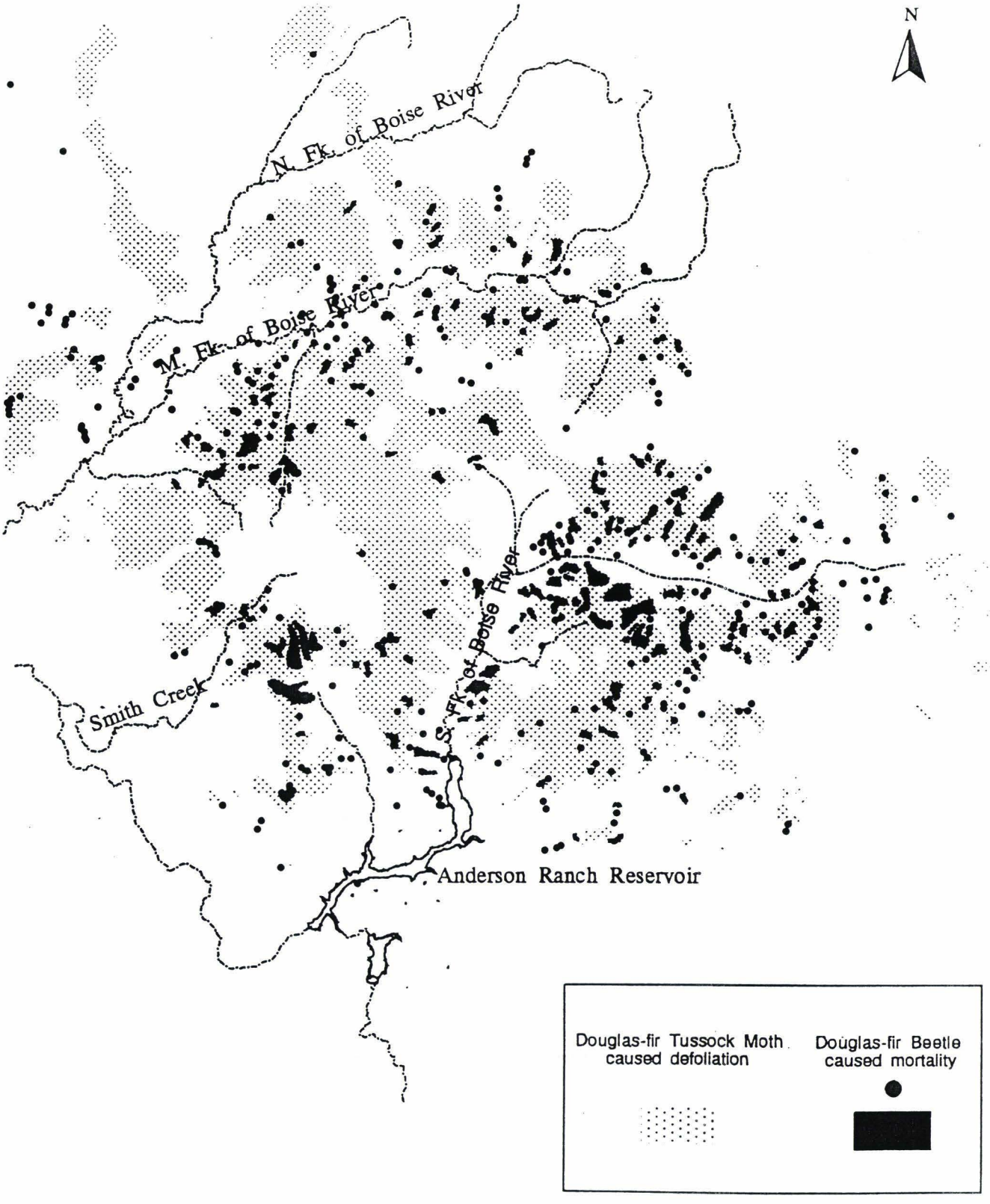

Figure 3. An overlay of Douglas-fir beetle caused mortality in 1995 and defoliation caused by Douglas-fir tussock moth in 1992 detected during annual aerial surveys of the Boise River Drainage.

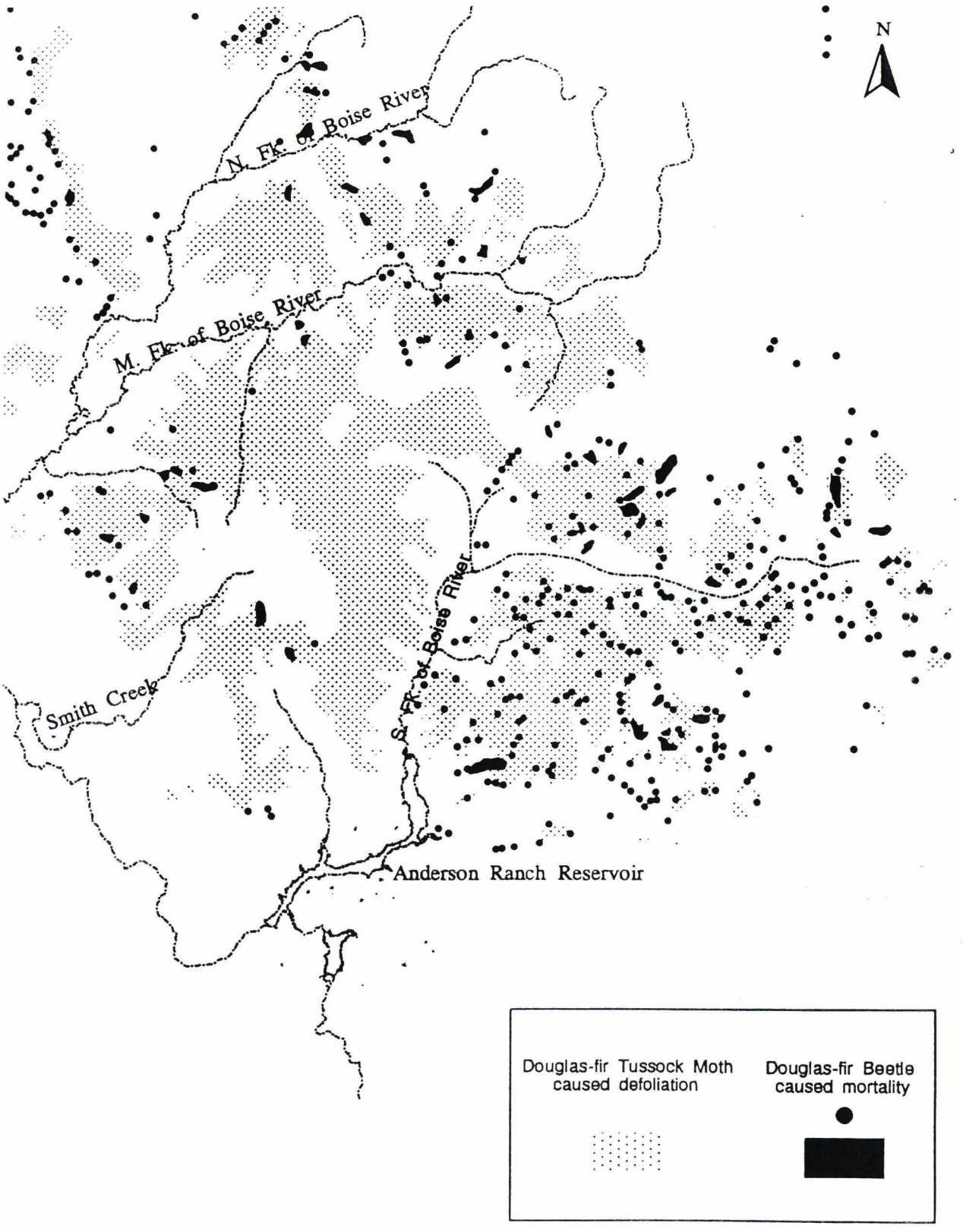

Figure 4. An overlay of Douglas-fir beetle caused mortality in 1991 and defoliation caused by Douglas-fir tussock moth in 1992 detected during annual aerial surveys of the Boise River Drainage.

Table 3. Comparison of live and dead tree stocking levels for all trees > 5" DBH obtained during early outbreak (1991) and post-outbreak (1995) impact sampling.

		Live Trees Per Acre								Dead Trees Per Acre		
Area/Line	Date	Total	DF	WL	AF	GF	PP	LP	AS	BB	DFTM	
V. Heavy Damage Class												
Elk Ck. 1	1991	42.4	25.3		17.0							
	1995	11.8	2.9		8.9					8.5 (DF)	14.0 (DF)	8.1 (AF)
Elk Ck. 3	1991	50.4	49.5				0.9					
	1995	15.5	14.6				0.9			3.7 (DF)	31.3 (DF)	
Abbot 21	1991	71.8	69.0				2.8					
	1995	16.1	13.3				2.8				55.7 (DF)	
Marsh 20	1991	52.2	46.6				5.7					
	1995	7.0	7.0				0.0				39.6 (DF)	5.7 (PP)
W. Kelley 5	1991	102.1	95.7				6.4					
	1995	28.0	28.0				0.0			6.4 (PP)	67.8 (DF)	
Mean	1991	63.8										
	1995	15.7									44.4	
Heavy Damage Class												
Elk 2	1991	178.6	178.6									
	1995	49.2	49.2							85.2 (DF)	34.6 (DF)	
Elk 4	1991	146.1	95.8						50.3			
	1995	66.6	16.3						50.3		79.5 (DF)	
Brownlee 2	1991	122.3	12.7			104.5	5.1					
	1995	112.9	12.7			95.1	5.1				9.4 (DF)	
Brownlee 3	1991	104.2				104.2						
	1995	93.8				93.8						
Marsh 15	1991	26.9	26.9									
	1995	22.9	22.9							2.4 (DF)	1.6 (DF)	
Marsh 19	1991	126.2	89.3						37.0			
	1995	23.7	23.7						0.0		65.6 (DF)	
N. Lime 4	1991	243.6	229.0						14.7			
	1995	46.0	31.3						14.7		197.6 (DF)	
W. Kelley 8	1991	149.4	149.4									
	1995	73.9	73.9								75.5 (DF)	
Mean	1991	137.2										
	1995	61.1									58.0	
Moderate Damage Class												
Phiffer 1	1991	161.6	134.7				26.8					
	1995	161.6	134.7				26.8					
Brownlee 4	1991	59.9	18.9	4.9		31.6	4.4					
	1995	56.5	18.9	4.9		28.3	4.4			3.3 (GF)		
Marsh 14	1991	107.0	107.0									
	1995	58.1	58.1							45.9 (DF)	2.9 (DF)	
Marsh 18	1991	56.2	20.7		19.9			15.6				
	1995	33.0	20.7		5.6			6.7		9.0 (LP)	14.3 (AF)	
Mean	1991	96.2										
	1995	77.3									4.3	

DF = Douglas-fir, WL = western larch, AF = subalpine fir, GF = grand fir, PP = ponderosa pine, LP = lodgepole pine, AS = aspen, BB = bark beetles, DFTM = Douglas-fir tussock moth

survival rate. We detected mortality centers caused by bark beetles on 3 of the 5 transects. Mortality centers averaged 6.2 trees per acre. Both Douglas-fir and ponderosa pine, *Pinus ponderosae* trees were attacked. The bark beetle caused mortality in ponderosa pine occurred in trees that had been 100 percent defoliated by Douglas-fir tussock moth even though ponderosa pine is not considered a host species.

In the heavy damage class, stocking levels averaged 137.2 trees per acre during the early phases of the outbreak. By 1995, stocking levels had been reduced to a mean of 61.1 trees per acre. This represents a 45 percent survival rate. Bark beetles were detected on 2 of the 7 transects. One of the mortality centers was large (85.2 trees per acre) and the other center was small (2.4 trees per acre).

In the moderate damage class, stocking levels averaged 96.2 trees per acre during the early phases of the outbreak. By 1995, stocking levels had been reduced to a mean of 77.3 trees per acre, which represents an 80 percent survival rate.

In Report No. R4-92-01 (Weatherby et al., 1992) predictions of mortality levels were made. These predictions were based on the initial data obtained from the impact plots in 1991. Four predicted mortality scenarios were displayed for the moderate, heavy and very heavy damage classes. The lowest mortality scenario predicted the number of trees per acre that would die if 25 percent of all the very heavily defoliated trees (>90 percent defoliated) died. The highest mortality scenario predicted the number of trees per acre that would die if 95 percent of all the very heavily defoliated trees died. This information is displayed in Table 4 along with the actual mortality calculated from data collected post-outbreak. Mortality rates observed in the field closely approximated the 95 percent mortality scenario. While we recognized the potential for this level of mortality, it was much higher than we expected.

Table 4. Comparison of the predicted (Weatherby et al. 1992) and actual numbers of trees per acre (>5" DBH) which died between 1991 and 1995 as a result of DFTM defoliation.

	Area Damage Classes		
	Moderate	Heavy	V.Heavy
Trees/Ac (>90 % defoliated)	10.2	64.3	44.8
Predicted Mortality (Trees/Ac)			
25 % mortality	2.5	16.1	11.2
40 % mortality	4.1	25.8	18.0
70 % mortality	7.1	45.0	31.4
95 % mortality	9.7	61.1	42.6
Actual Mortality (Trees/Ac)	4.3	58.0	44.4

Our ground survey database contains 215 defoliated Douglas-fir trees and 110 defoliated grand fir trees that we followed from 1991 to 1995. Defoliation levels for each of these trees were estimated in 1991 and the fate of each tree was followed annually through 1995. Survival rates are inversely related to the level of defoliation. Survival rates dropped significantly when defoliation levels exceeded 79 percent for Douglas-fir trees and 89 percent for grand fir trees (Figure 5). Five defoliation classes were developed for both Douglas-fir and grand fir trees (DF; class I = 0-9 percent defoliation, class II = 10-79 percent defoliation, class III = 80-89 percent defoliation, class IV = 90-99 percent defoliation, and class V = 100 percent defoliation: GF; class I = 0-9 percent defoliation, class II = 10-49 percent defoliation, class III = 50-89 percent defoliation, class IV = 90-99 percent defoliation, and class V = 100 percent defoliation).

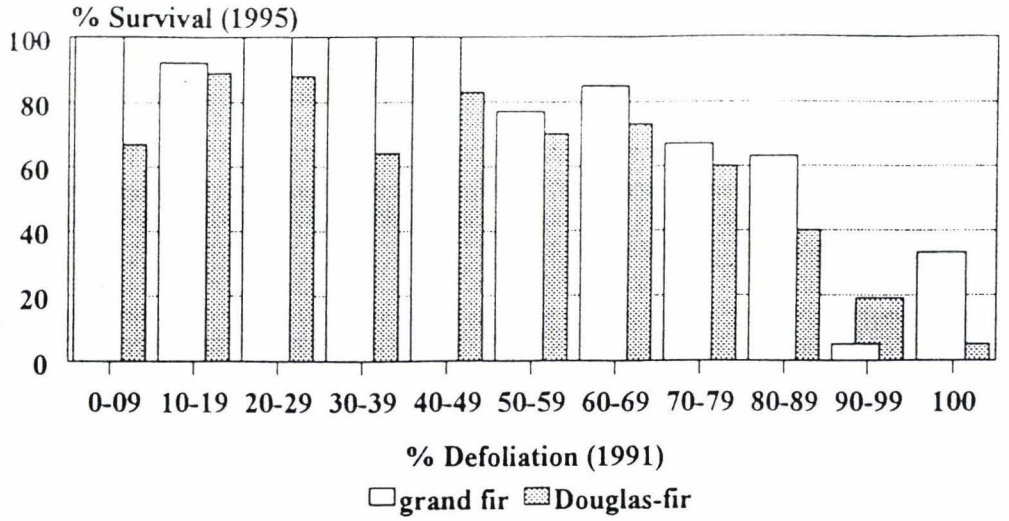

Figure 5. Percent survival (1995) by defoliation class for grand fir and Douglas-fir sample trees (> 5" DBH) located in impact plots established in 1991.

Annual mortality rates for each defoliation class are displayed in Tables 5 and 6. More than half of the Douglas-fir trees that were completely defoliated in 1991 died during the first year following defoliation. Only 5 percent of the sample trees in this defoliation class remained alive at the last sampling date in 1995. We detected no mortality caused by bark beetles in this defoliation class. First-year post-defoliation mortality levels for Douglas-fir trees in the 90 to 99 and the 80 to 89 percent defoliation classes were 27 and 13 percent, respectively. Additional mortality occurred through 1995. Eighty-one percent of the Douglas-fir trees in the 90 to 99 percent defoliation class and 60 percent of the Douglas-fir trees in the 80 to 89 percent defoliation class died between 1991 and 1995. In both of these classes a significant proportion of the mortality was attributable to bark beetles particularly during 1992. In the 0 to 9 percent defoliation class and in the 10 to 79 percent defoliation class, mortality was fairly low and concentrated toward the end of the 5 year post-defoliation period.

A high proportion of the mortality in these classes was attributable to bark beetles. It appears that totally defoliated trees were not particularly attractive or suitable for colonization by bark beetles while moderately defoliated trees were more likely to be attacked soon after defoliation. Slightly defoliated trees were not attacked until 1994 and 1995 perhaps indicating that the beetles were moving or expanding from the moderately to slightly defoliated trees.

Table 5. Percent mortality of defoliated Douglas-fir trees (> 5" DBH) following the 1990 to 1992 DFTM outbreak. Total percent mortality includes mortality attributed to DFTM defoliation and bark beetle infestation.

Levels of Defoliation	No. Live Trees 1991	Percent Mortality 1992		1993		1994		1995	
		Total	BB	Total	BB	Total	BB	Total	BB
0-9 %	18	0	0	0	0	6	6	27	27
10-79 %	104	4	1	1	1	8	0	8	8
80-89 %	15	13	7	27	0	20	7	0	0
90-99 %	37	27	11	14	3	35	0	5	0
100 %	41	59	0	26	0	10	0	0	0

Table 6. Percent mortality of defoliated grand fir trees (> 5" DBH) following the 1990 to 1992 DFTM outbreak. Total percent mortality includes mortality attributed to DFTM defoliation and bark beetle infestation.

Levels of Defoliation	No. Live Trees 1991	Percent Mortality							
		1992		1993		1994		1995	
		Total	BB	Total	BB	Total	BB	Total	BB
0-9 %	2	0	0	0	0	0	0	0	0
10-49 %	46	0	0	0	0	0	0	2	2
50-89 %	40	3	0	5	0	15	0	2	0
90-99 %	19	11	0	63	0	5	0	16	0
100%	3	67	0	0	0	0	0	0	0

Sixty-seven percent of all of the grand fir trees that were completely defoliated in 1991 died during the first year following defoliation. No additional mortality occurred through 1995 in this defoliation class. Most of the grand fir trees in the 90 to 99 percent defoliation class survived through 1992; however, mortality rates increased dramatically in 1993. By 1995, only 5 percent of the grand fir trees in this defoliation class survived. Twenty-five percent of the grand fir trees in the 50 to 89 percent defoliation class died by 1995. Very little mortality was recorded for grand fir trees with less than 50 percent defoliation. Only 1 transect had any grand fir mortality attributed to bark beetles.

SUMMARY

The 1990 to 1992 DFTM outbreak in southern Idaho caused extremely high levels of mortality in very heavily defoliated stands of Douglas-fir and grand fir. This outbreak coincided with a significant drought period that probably contributed to the high levels of mortality. Douglas-fir beetle caused mortality coalesced within the DFTM outbreak boundaries suggesting that the stress associated with defoliation probably contributed to the increase in Douglas-fir beetle activity.

LITERATURE CITED

Brookes, M.H.; Stark, R.W.; Campbell, R.W., editors. 1978. The Douglas-fir tussock moth: a synthesis. Tech. Bull. 1585. Washington, D.C.: USDA, Forest Service, 331 p.

Daterman, G.E.; Livingston, R.L.; Wenz, J.M.; Sower, L.L. 1979. How to use pheromone traps to determine outbreak potential. Agricultural Handbook 546. Washington, D.C.: USDA, 11p.

Knapp, A.; Weatherby, J.C.; Hoffman, J.; Hansen, D.; LaMadeleine, L.; Williams, R. 1991. Forest insect and disease conditions in the Intermountain Region 1990. Ogden, UT: USDA, Forest Pest Management, 33p.

Knapp, A.; Weatherby, J.C.; Hoffman, J.; Munson, S.; Guyon, J.; LaMadeleine, L.; Williams, R. Forest insect and disease conditions in the Intermountain Region 1991. Ogden, UT: USDA, Forest Pest Management, 39p.

Knapp, A.; Hansen, D.; DeBlander, V.; Williams, R.; LaMadeleine, L. 1993. Forest insect and disease conditions in the Intermountain Region 1992. Ogden, UT: USDA, Forest Pest Management, 34p.

Weatherby, J.C ; Knapp, K.A.; Gardner, B.R.; Roberts, J.; Mocettini, P. 1992. A biological evaluation of the Douglas-fir tussock moth outbreak in southern Idaho, 1991. Report No. R4-92-01. Ogden, UT: USDA, Forest Pest Management, 51p.